

Prognostics Framework

NDIA SEC Conference, San Diego CA

Presented By:

Ms. Mary Nolan, Giordano Automation Corp.

Authors:

Dr. Li Pi Su, U.S. Army TMDE

Ms. Becky Norman, Giordano Automation Corp.

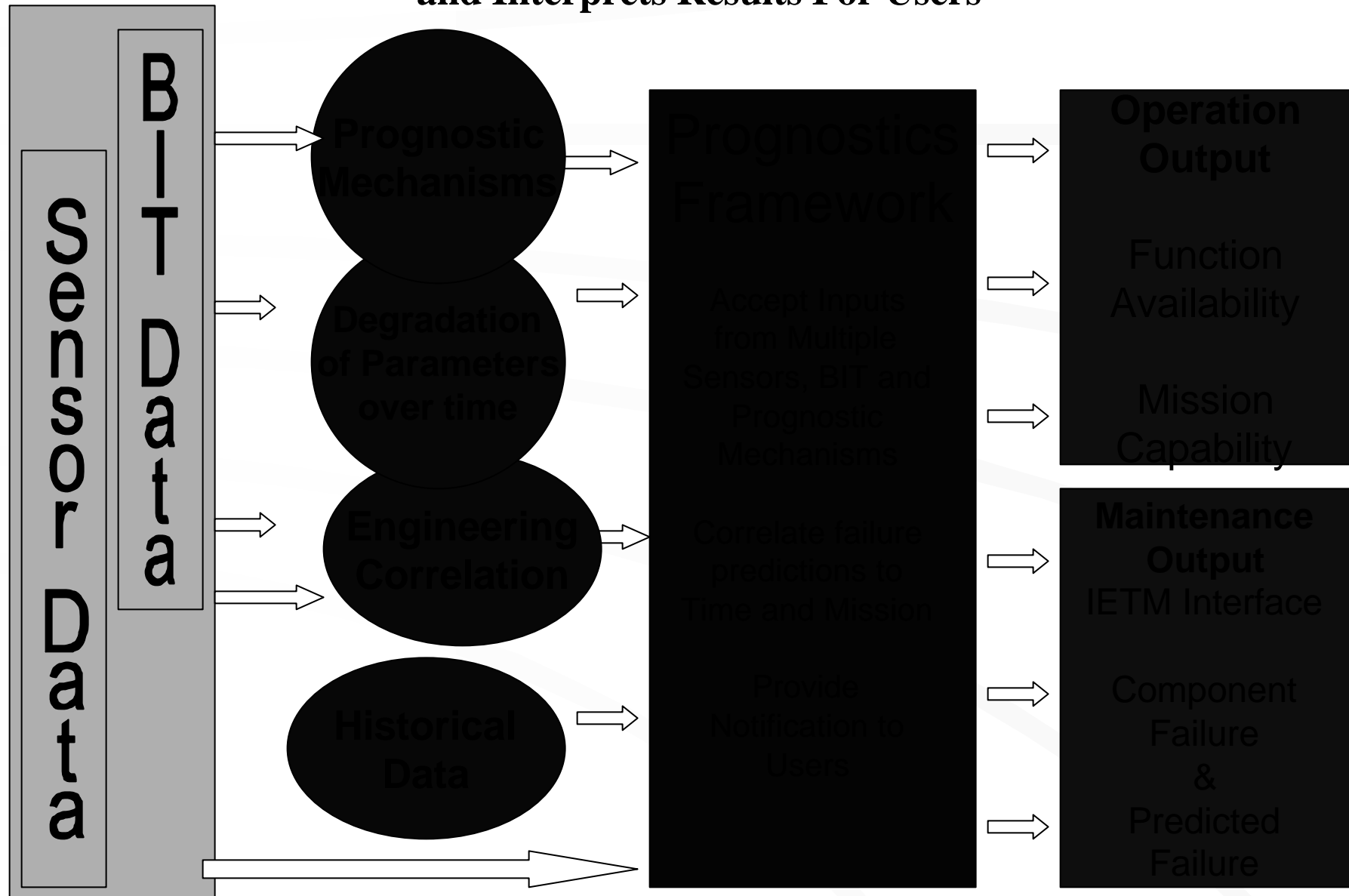
Mr. Greg de Mare, Giordano Automation Corp.

What is the Prognostics Framework?

A System-level prognostic/diagnostic capability

- Integrates sub-system/component specific diagnostic & prognostic software, BIT and parametric data using a “divide and conquer” strategy
- Provides a complete overall system health monitoring and management capability
- Reports on functional capability & mission readiness to aid operations decisions
- Anticipates maintenance workload & provides repair information - interfaces to maintenance aids and support systems

The Prognostics Framework Integrates Prognostics Mechanisms and Interprets Results For Users



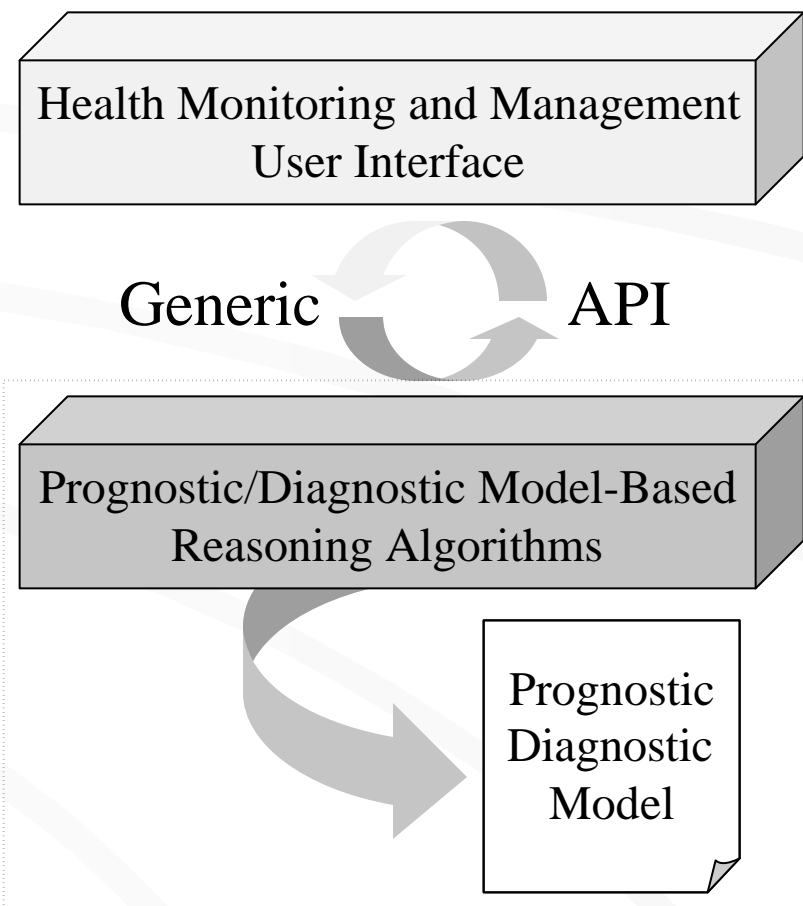
Predictive Techniques Incorporated

- Advanced, Item-Specific Prognostic Mechanisms (ANN, etc.)
- Linear Degradation of Signals / Measurements over time
- Historical Conclusions / Statistics
- Engineering Correlations

What is the Prognostics Framework?

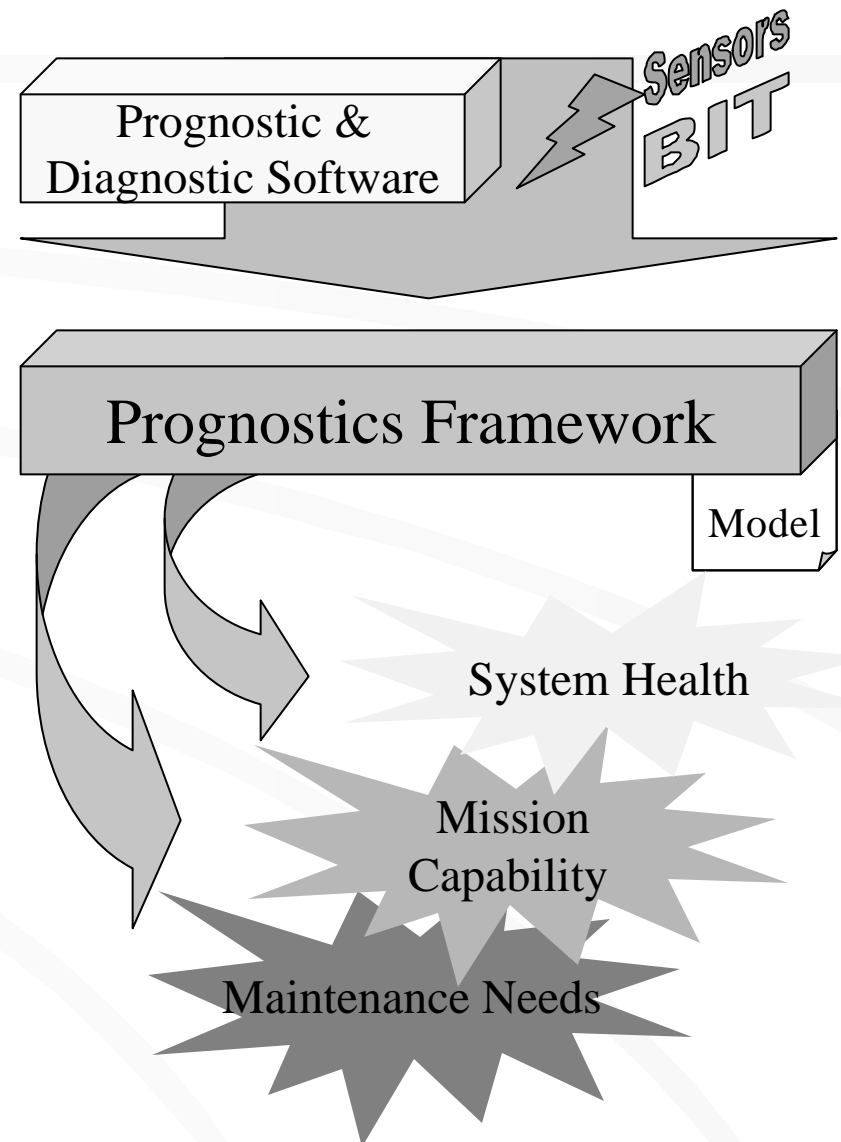
Generic Open Architecture

- Generically applicable open architecture software system
- Can be applied to existing and new weapon systems
- Can be embedded or off-board (real-time or near real-time)



How does the Prognostics Framework work?

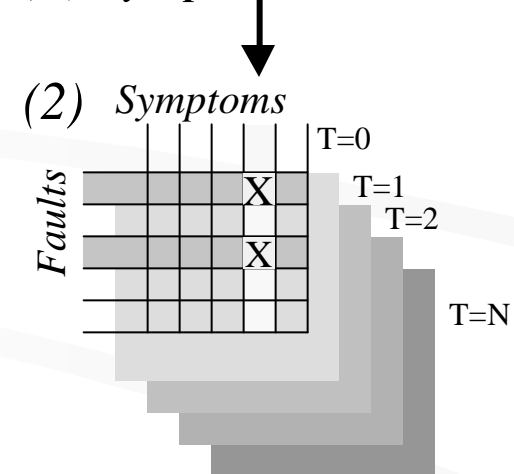
- Embedded Environment
 - Monitors data inputs from sensors, BIT, and other prognostic/diagnostic mechanisms
 - Prognoses/Diagnoses failures in real time
 - Provides complete system monitoring
- Off-line Environment
 - Accepts all data available
 - Additional Prognosis/Diagnosis
 - Provides complete system health management
 - Anticipates maintenance needs
 - Integrates logistics software



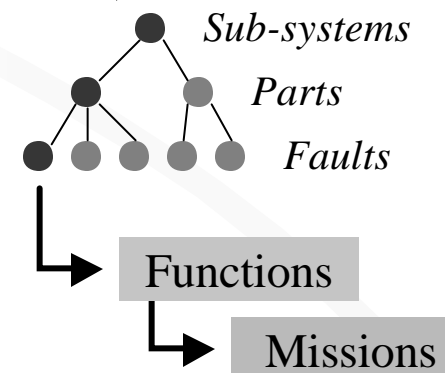
How does the Prognostics Framework reason?

1. Accept prognostic/diagnostic software outputs, BIT and parametric data as *symptoms*
2. Apply model-based reasoning AI algorithms to prognose/diagnose the implication of out of tolerance *symptoms* on each future time point defined in the model
3. Identify the components and sub-systems affected by predicted failures - *sub-system health*
4. Identify the functions and missions affected by predicted failures - *mission readiness*
5. Identify the repair actions needed - *anticipatory maintenance*

(1) *Symptom Data*

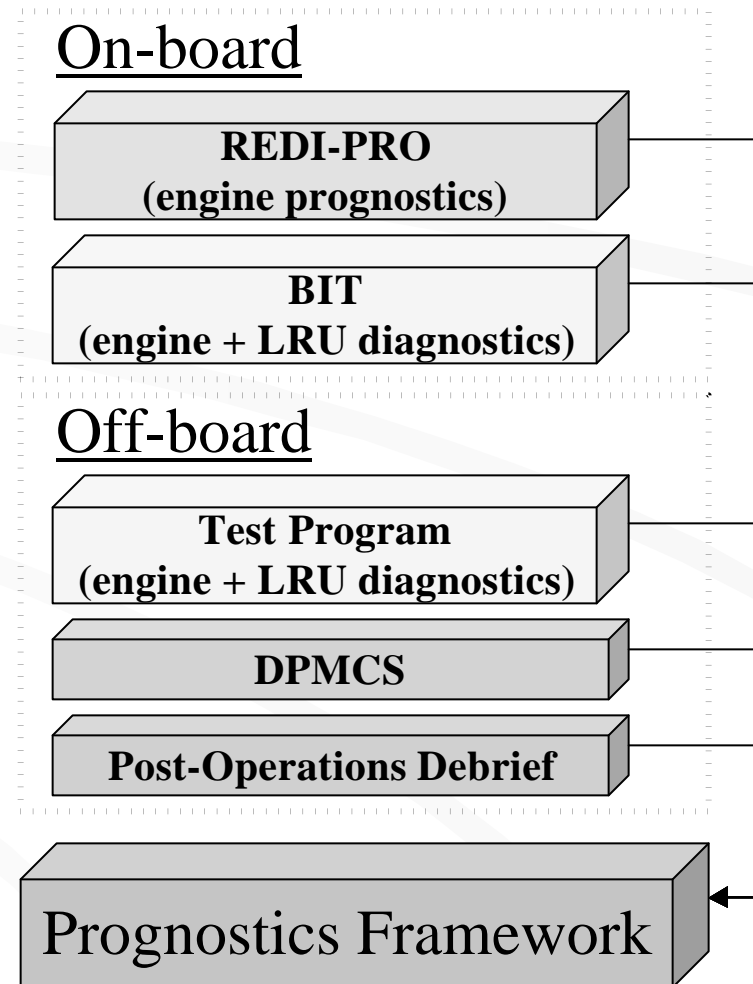


(3, 4, 5)



M1A1 Abrams WSSPR Demonstration Prognostic/Diagnostic System Integration

- Engine prognostic inputs from REDI-PRO
- Engine & LRU BIT
- Off-line diagnostic test results
- DPMCS observations from maintenance crew
- Post-Operations Debrief for anomaly filtering
- Prognostic Framework provides additional prognostics/diagnostics



M1A1 Abrams WSSPR Demonstration

Health Management

- Provides an at-a-glance view of system health
- sub-system status
- sub-system degradation criticality to operation

Prognostic Framework Demo 1 (11-23-99)

View Operator Maintenance Exit

Abrams

Display

☒ SubSystem ☐ Mission/Function ☐ Maintenance

Faults Only Detail

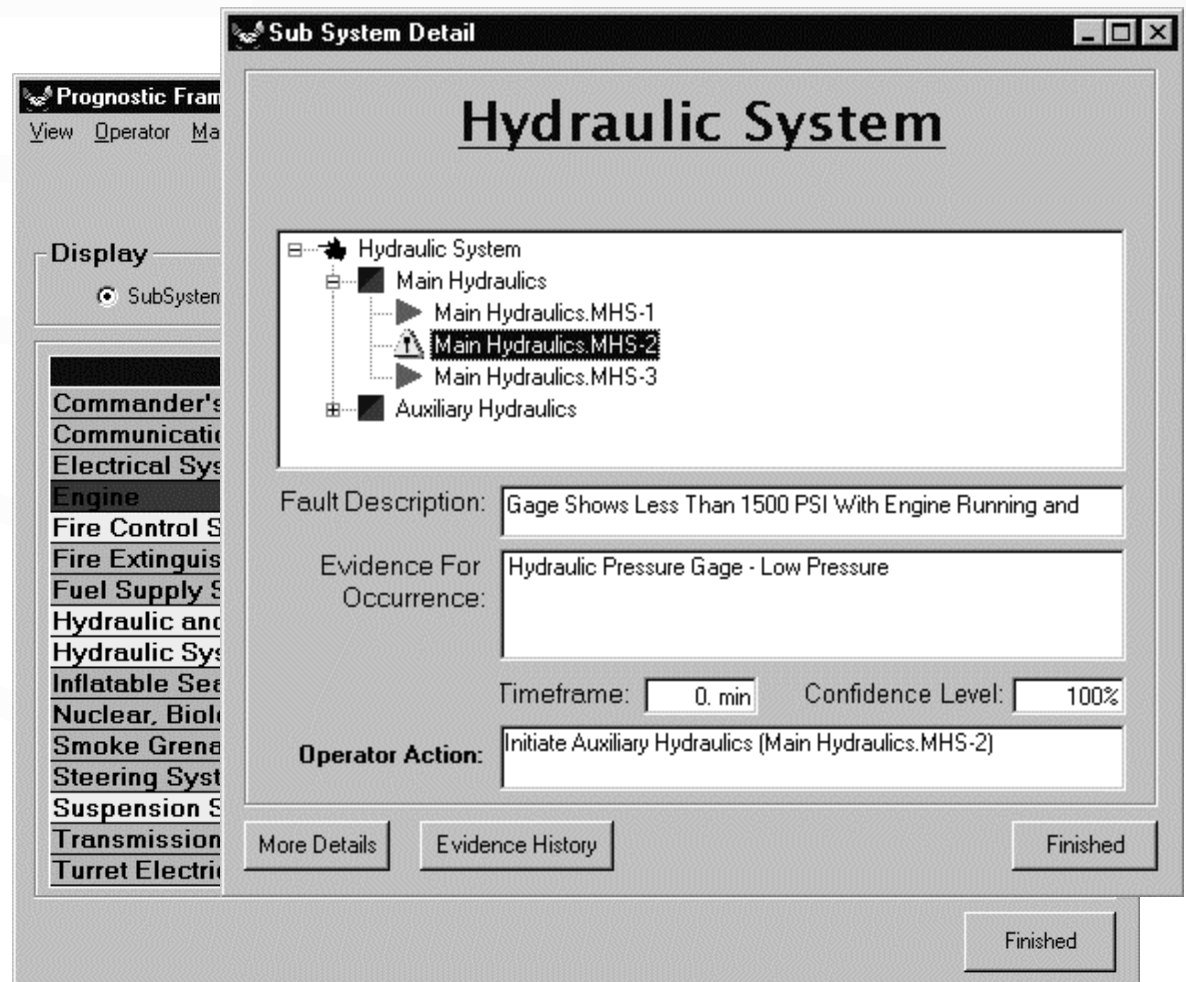
SubSystem	Condition	Criticality	Time Frame
Commander's Weapon Station	Operational	Not Critical	None
Communication System	Operational	Not Critical	None
Electrical System	Operational	Not Critical	None
Engine	Fault Exists	Critical	Current
Fire Control System	Fault Exists	Not Critical	Current
Fire Extinguisher System	Operational	Not Critical	None
Fuel Supply System	Operational	Not Critical	None
Hydraulic and Gun/Turret Drive	Fault Exists	Not Critical	Current
Hydraulic System	Fault Exists	Not Critical	Current
Inflatable Seal System	Operational	Not Critical	None
Nuclear, Biological, Chemical System	Operational	Not Critical	None
Smoke Grenade System	Operational	Not Critical	None
Steering System	Operational	Not Critical	None
Suspension System	Fault Impending	Not Critical	35. min
Transmission and Final Drive System	Operational	Not Critical	None
Turret Electrical	Operational	Not Critical	None

Finished

M1A1 Abrams WSSPR Demonstration

Health Management

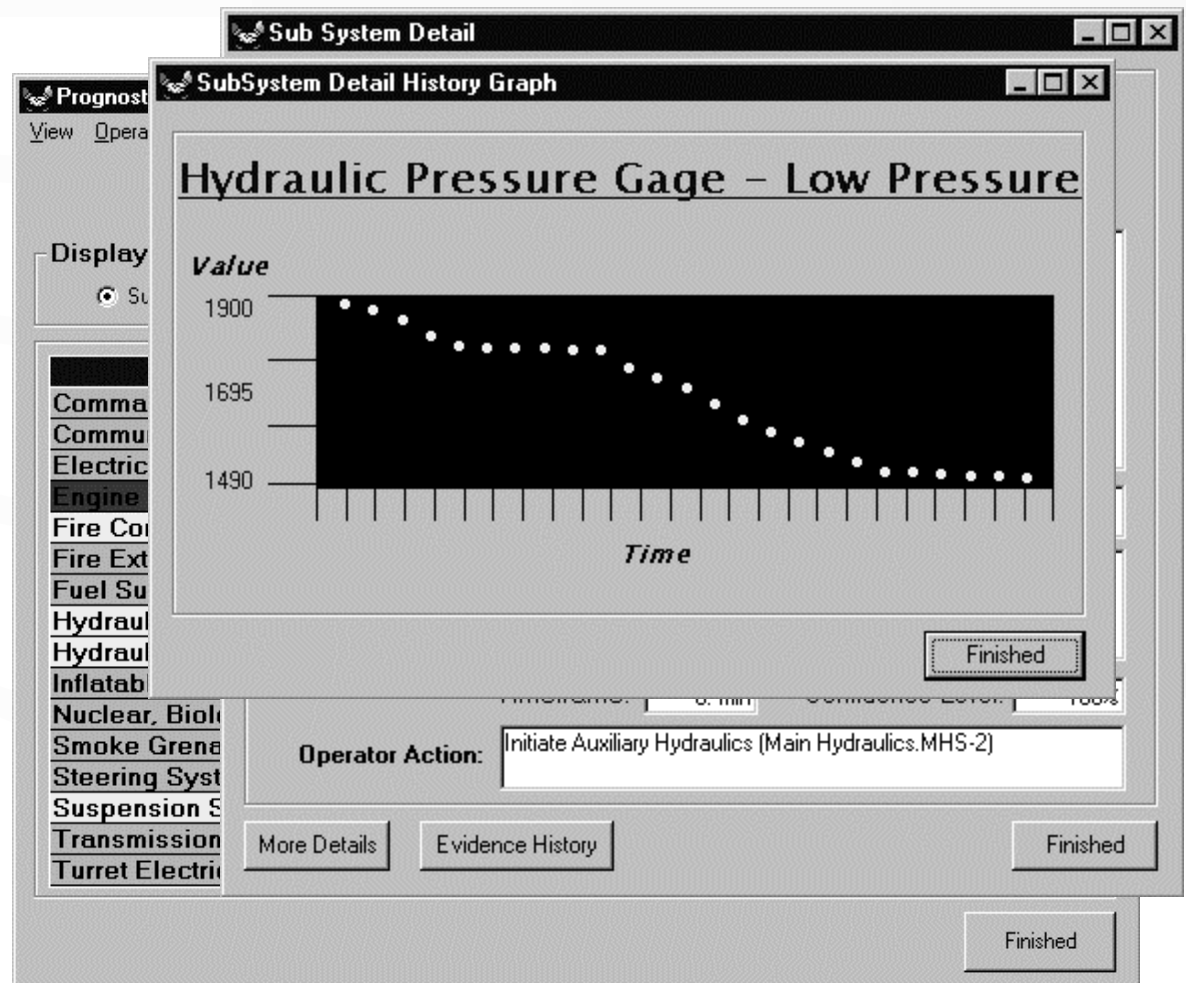
- Sub-system details
- Hierarchical breakout of the sub-system
- Evidence for failure



M1A1 Abrams WSSPR Demonstration

Health Management

- Prognostic Framework logs all data received
- Degradation over time



M1A1 Abrams WSSPR Demonstration

Health Management

- Impact of Functional degradation on specific missions over time
- What functions are available?
- Mission Readiness



M1A1 Abrams WSSPR Demonstration

Maintenance Support

- Current & anticipated maintenance workload
- Supports integrated IETMs, parts ordering
- Preventative maintenance
- Logistics planning
- Repair history is logged

The screenshot shows a software window titled "Prognostic Framework Demo 1 (11-23-99)". It has a menu bar with "View", "Operator", "Maintenance", and "Exit". A large "Abrams" label is centered. Below it, a "Display" section has three radio buttons: "SubSystem", "Mission/Function", and "Maintenance" (which is selected). To the right of these are "View All" and "Detail" buttons. The main area contains a table with four columns: "Repair Item", "Condition", "Action", and "Part Order". The table lists five items: Fuel Injection Nozzle, Main Hydraulic, Main Hydraulics, Manual SelfTest, and Suspension System. The first four have a "Fault Exists" condition, while the last has "Fault Impending". The "Action" column contains symptom codes and TM numbers. The "Part Order" column lists part numbers and cage numbers. At the bottom right are "Order" and "Finished" buttons.

Repair Item	Condition	Action	Part Order
Fuel Injection Nozzle	Fault Exists	Symptom ESS-6: TM 9-2350-255-20-1	Part #12302053, Cage 19207
Main Hydraulic	Fault Exists	Symptom MHS-2: TM 9-2350-255-20-2	Part #D12025-001, Cage 14798
Main Hydraulics	Fault Exists	Symptom MHS-2: TM 9-2350-255-20-2	Part #D12025-001, Cage 14798
Manual SelfTest	Fault Exists	Symptom LRF-4: TM 9-2350-255-20-2	Part #12272900, Cage 19200
Suspension System	Fault Impending	Symptom SSS-12: TM 9-2350-255-20-1	Part #5705483, Cage 19207

M1A1 Abrams WSSPR Demonstration

Maintenance Support

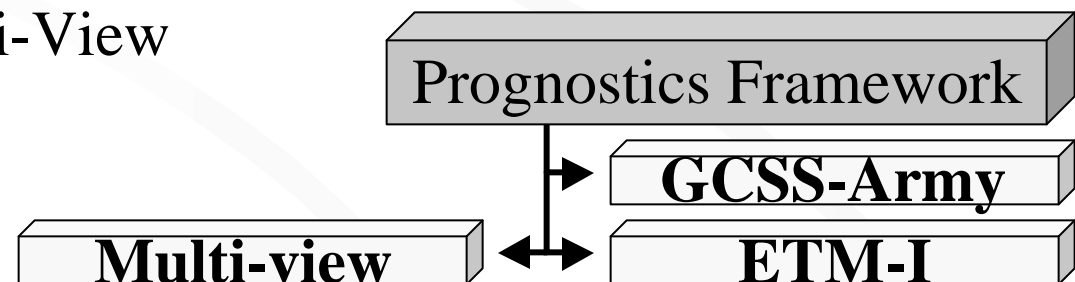
- Prognostic Framework pre-populates the necessary maintenance info
- Interfaces with GCSS-A via DTD/XML tagged data
- Interfaces with ETM-I parts ordering via MS-Access database
- Interfaces with Multi-View logistics network

Mechanic Request For Issue Order Form

DODAAC WK4WRC

Admin Number	656	Fault Date	19-Sep-00
Mechanic License	N6516	Fault Time	19:25:05
NIIN	5705483	Part Noun	END CONNEX
Cage Number	19207	Quantity	00001
Fault Description	WORN T-156 END CONNECTOR		
How Recognized	387 = Low Performance		
When Discovered	D = Normal Operation		
Fault Symbol	X = Deadline		
Fail Code	020 = Deterioration		
Maintenance Type	U = Unscheduled Maintenance		

Cancel OK



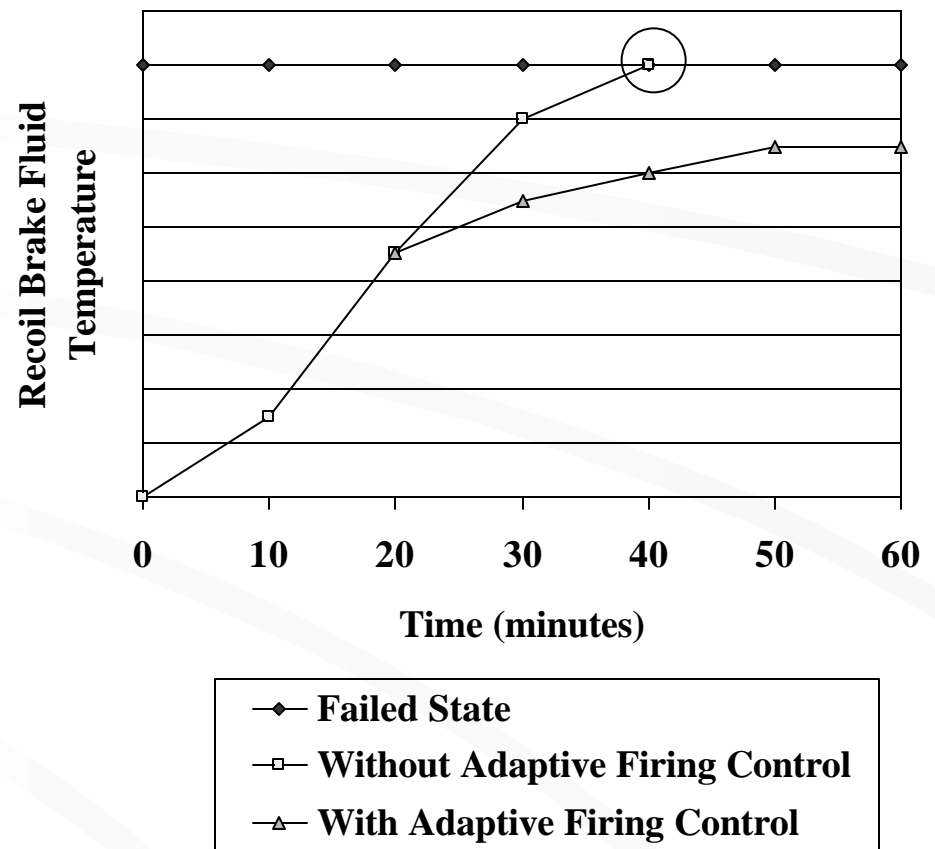
Generalized Information Architecture

- System Design Data (parts, faults)
- Diagnostic/Prognostic Input Descriptions (data definitions, format, location) - REDI-PRO, BIT, Sensor data, etc.
- Diagnostic/Prognostic Preprocessing (mathematical calculations, functions, and filtering)
- Prognostic Times to be Extrapolated during runtime
- Fault/Symptom/Time matrix for failure descriptions
- Operational Support Information - missions, functions, operational actions
- Maintenance Support Information - URL links to other software system, part numbers, ordering information

Army FCS Armament: Viking Program (TC2)

Adaptive Firing Control

- Monitor armament temperature/stress
- Dynamically adapt rate of fire to avoid an out of tolerance condition
- Manage system degradation
- Maximize armament performance



Real-time system monitoring!

Army FCS Armament: Viking Program (TC2)

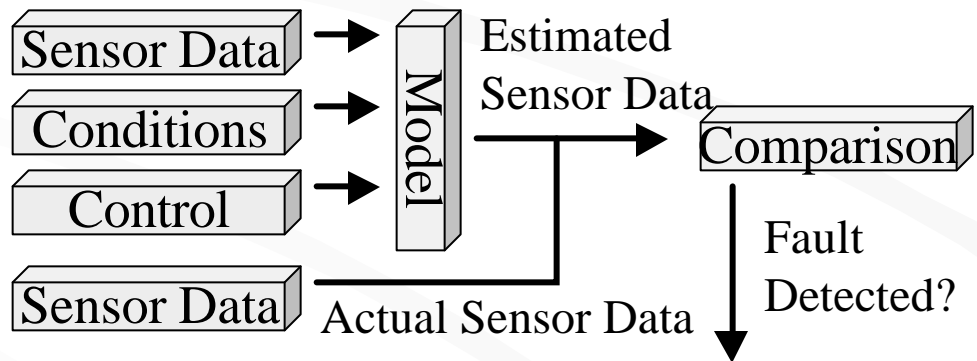
Integrated Mathematical Model Approach

- Tighter threshold based on estimated sensor reading for specific operating conditions and control commands
- Increased fault detection
- Reduces false alarms and false dismissals
- Enables sensor validation based on inherently redundant sensor info

Conventional Approach



Adaptive Threshold Approach



Flexibility!

Army FCS Armament: Viking Program (TC2)

Health Management

- Integrates all system prognostic & diagnostic data
- Provides total armament health monitoring
- Expandable to other FCS subsystems
- Integrates maintenance requirements - IETM, parts ordering



Expandable!

Summary

- Allows a system to optimize diagnostic capability
- Maximizes the use and effectiveness of BIT/BITE information
- Provides a divide and conquer approach
- Framework allows system managers to CONVERGE on prognostic capability as applications and technologies mature